

# FEC Structures for 400GbE Supporting Multi-PMDs

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### **MOTIVATION**



 To introduce a new and detailed FEC structure (in addition to three FEC strategies presented so far) for the consideration of 400GbE.



# **POSSIBLE FEC STRATEGY FOR 400GBE**

#### Three FEC strategies were discussed in May meeting (gustlin\_3bs\_02\_0514)

- End to end
- 2) Segment by segment
- 3) Encapsulated FECs

#### • The following strategy was discussed in Sep. meeting [1]

- 1) Use (interleaved ) RS(528, 514) code as base FEC
- 2) Add extra parity at PMD level



[1] Z. Wang, "FEC Configuration Analyses for 400Gb Ethernet," Sep. 2014. http://www.ieee802.org/3/bs/public/14\_09/wang\_z\_3bs\_01\_0914.pdf

### **PREVIOUSLY DISCUSSED FEC CODES [2]**



- KR4 FEC: RS(528, 514, t=7, m=10) : 1.0X HW
- KP4 FEC: RS(544, 514, t=15, m=10): 2.5X HW
- BCH1 (2858, 2570, t=24): CG ~ 8.7dB, 10X HW
- BCH2 (9193, 8192, t=71): CG > 9.0dB, 40X HW
- We are not ready to specify target CG for FEC as modulation scheme and channel specification are not finalized yet.
- Previous presentations seem to suggest
  - No stronger code than KP4-FEC may be needed with NRZ modulation
  - CG of 8+ dB may be needed with PAM4 modulation (in some case)
  - CG of 9+ dB may be needed with DMT modulation (in some case)

[2] M. Langhammer, "FEC Core Area Comparison and Model," IEEE 400GbE ad hoc meeting, Oct., 2014



- In practice, either KR4 or KP4 FEC is easy to implement and not much power-consuming.
- To achieve a CG of 9+dB, using BCH2 is neither power efficient nor hardware efficient (see [2]). Need consider a better method.
- This presentation will focus on FEC structures for PAM4 modulation. Extension to DMT modulation is possible.

## **REVISIT MULTI-LEVEL CODING (MLC)**



 One (generic) MLC scheme for communication systems based on PAM4 modulation is shown below, where P/S denotes parallel-to-serial conversion, and "Enc-1" and "Enc-2" denote encoder for Code-1 and Code-2 respectively.



# A PROPOSED FEC STRUCTURE



- A multi-mode FEC structure based on distributed MLC concept.
- The MLC encoding process is done in 2 separate locations.
- Code-1 can select KR4 FEC or any other light FEC.
- Code-2 uses a strong FEC. It can also be an umbrella code consisting of mother code and daughter code.
- Ex-1: Code-1 uses KR4 FEC, m=69, n=63
  Code-2 uses RS(552, 504, t=24, m=10). OC =4.5%
- Ex-2: Code-1 uses RS(520, 514, t=3), OC=3%
  - Inner mother code: RS(544, 496, t=24),
  - Inner daughter code: RS(272, 248, t=12).



#### **ANALYSES**



- Noise1+noise3 will be handled by 1st FEC.
- Noise2 will be mainly handled by 2<sup>nd</sup> FEC.
- Being different from any of 3 existing FEC strategies:
  - No immediate decoder after 1<sup>st</sup> encoder
  - Code-1 is collaborating with Code-2.
- Ensure fixed data rate for CDXI-n
- Decoding is done in two steps, which can correct errors occurred in different segments.
- As strong FEC only covers half data rate, overall FEC power consumption is significantly reduced.

## ANALYSES (CONT'D)



- Switch doesn't need to embed strong FEC.
- If burst errors are well controlled, either code-1 or code-2 can be selected as BCH code.
- To support multi-PMDs, one
  - Can let Code-2 use umbrella code to provide tradeoffs between coding gain, power, and latency while ensuring same clocking rate all the time
  - Can bypass 2<sup>nd</sup> part of MLC encoding for good channels
  - Could have different redundancy ratio in the 2<sup>nd</sup> portion of MLC encoding for different PMDs.



### **FEC CANDIDATE CODE WITH 8+DB CG**

#### • Use MLC-based umbrella coding (MLC-UC):

- Ex-3: Code-1 uses RS(528, 514, t=7), OC=9%
  - Inner daughter code: RS(144, 120, t=12),
  - Inner mother code: RS(288, 240, t=24).
  - CG > 8.5dB
  - Power: < 3.5X KR4-FEC

### SUMMARY



- We have presented distributed MLC (dis-MLC) schemes to support multiple PMDs, which is an additional option to existing 3 FEC strategies.
- Detailed parameters such as FEC component codes, overclocking ratio, number of FEC modes, et al, will be decided after the required coding gains for FEC in various cases are determined.